TABLE 6-1
(page 3 of 4)

SYSTEM	NUMBER OF UNITS	UNIT COST ($MILL.)	INITIAL COST ($MILL.)	REPLACEMENT COST[b] ($MILL.)
3. EARTH EXPLORATION SERVICE (Satellite Networks)				
A. LANDSAT	2	150	300[k]	1037
B. NIMBUS 7	NA	NA	NA	NA
C. Geosynchronous Operational Environmental Satellite (GOES)	5	NA	900[l]	900[j]
D. NOAA Television Infrared Observational Satellite (TIROS)	NA	NA	NA	NA
E. Defense Meteorological Satellite Program (DMSP)	SEE TABLE 5-1			
4. SPACE OPERATION SERVICE (Satellite Networks)				
A. Array of Low Energy X-rays Imaging Sensors (ALEXIS)	SEE TABLE 5-1			
B. Orbiting Maneuvering Vehicle (OMV)	1	30	30[m]	40
C. Polar Plasma Laboratory and Wind Spacecraft	2	NA	NA	NA
D. Fleet Satellite Communication (FLTSATCOM)	NA	NA	NA	NA
E. Fleet Satellite Communication-C (FLTSATCOM-C)	SEE TABLE 5-1			
F. Defense Satellite Communication System (DSCS) - II, III, and Follow-On	SEE TABLE 5-1			
G. Inertial Upper Stage (IUS)	SEE TABLE 5-1			

TABLE 6-1
(page 4 of 4)

SYSTEM	NUMBER OF UNITS	UNIT COST ($MILL.)	INITIAL COST ($MILL.)	REPLACEMENT COST[b] ($MILL.)
5. FIXED SERVICE				
A. Line-of-Sight, Point-to-Point Systems	308[n]	0.05[o]	15	38
B. Vessel Traffic System	2	NA	11[p]	27
C. ACMI/ACMR/TACTS	NA	NA	2[q]	3
6. MOBILE SERVICE				
A. Air/Ground, Air/Air and Ground/Ground Video Data Links				
(1) Charge Coupled Device Seeker System	2	0.0125	0.025	0.065
(2) AN/DKT-71	53	0.051	3	4
(3) Titan III	4	0.040	0.16	0.3
(4) Titan IV	65	237.3[r]	15430	15430
(5) Vector T-100 S/L Series	1000	0.007	7	10
(6) Omitek TX 501	30	0.133	4	4.4
(7) Microcom T902	500	0.006	3	3
(8) Earth Resource (ER-2) High Altitude	NA	NA	0.14	0.2
(9) M/A COM Model MA-2.5MX Transmitter and Model Super 2MR Receivers	7	0.029	0.203	0.3
B. Tethered Radar Balloons/SEEK SKYHOOK	SEE TABLE 5-1			
C. Scoring Systems (Telemetry Link)				
(1) Airborne				
i) AN/USQ-X	NA	NA	9.7	16
ii) AN/DSQ-50	200	0.0375	7.5	9
iii) Others	NA	0.030[s]	NA	NA
(2) Ground				
i) Floating at Sea Target System (FAST)	SEE TABLE 5-1			

FOOTNOTES TO TABLE 6-1

[a]The initial and replacement costs are based on current available documentation. These are non-recurring costs only.

[b]When specific estimates are not available, the replacement cost is either based on an assumed annual inflation rate of 10% (e.g., for space systems, mobile systems, etc.) or cost of $250,000 per new station (e.g., for fixed line-of-sight, point-to-point systems). For systems under the developmental stage, the replacement cost is assumed to be at least the initial cost.

[c]Earth tracking earth stations located worldwide.

[d]System not yet operational.

[e]Total SDI spending authority in fiscal year 1990.

[f]Includes four operational satellites, one spare satellite and an earth station.

[g]Cost of the system procured on a 10-year lease basis.

[h]Two satellites and an earth station.

[i]The value represents the cost of the AMPTE/CCE satellite launched by the U.S. The remaining two satellites are being provided by the Federal Republic of Germany and the United Kingdom.

[j]The value represents the current (1990) cost.

[k]Cost is based on LANDSAT D System.

[l]Cost is for GOES I through GOES M, including ground support equipment.

[m]Combined cost of the communications and tracking subsystem.

[n]Total fixed assignments in the band.

[o]Assumed cost per fixed link.

[p]Cost includes the Vessel Traffic Systems in New York and New Orleans.

[q]Cost is only for the TACTS radio relay operating along the East Coast of the U.S.

[r]Procurement cost for 75 Titan IV vehicles until 1992.

[s]Cost per unit is based on the per unit cost of the Bullet Hit Indicator and the Miss Distance Indicator Systems.

A short functional summary of the major systems in the 2200-2290 MHz band is given below. The space usage in this band is basically limited to systems operated by the U.S. Air Force and NASA, except for the "GOES" which is operated by DOC. These systems or satellite networks are enumerated and briefly discussed under their respective service categories. Special systems such as: the Spaceflight Tracking and Data Network (STDN) under the system management and technical direction of the Goddard Space Flight Center which supports manned and unmanned Earth-orbiting and lunar scientific and advanced technology satellites; and the Tracking and Data Relay Satellite System (TDRSS) and its subsequent upgrade system are described under "Space Systems."

MAJOR UNCLASSIFIED SYSTEMS OPERATING OR PLANNED FOR OPERATION IN THE 2200-2290 MHz BAND

Major systems listed below that also operate in the 1710-1850 MHz band are not discussed further in this chapter. Included in the category are some space and satellite networks that use the SGLS uplink band (i.e., 1761-1842 MHz) for tracking, telemetry, and command operations. These systems were previously discussed in Chapter 5. A good number of space systems operating in the 2200-2290 MHz band receive data from other uplink bands, in particular --- the 2025-2110 MHz band.[*]

SPACE SYSTEMS

SGLS. Discussed previously in Section 5.

Automated Remote Tracking System (ARTS). Discussed previously in Section 5.

Spaceflight Tracking and Data Network (STDN)

NASA maintains a worldwide system of ground tracking stations to provide tracking, telemetry, and command to all authorized user spacecraft missions. The set of ground stations presently supporting the low Earth-orbiting spacecraft and the high, eccentric, or synchronous orbit spacecraft, together with the communication links connecting NASA centers with the ground stations, is referred to as the STDN.

[*]The 2025-2110 MHz band is not considered in this report.

In the 1980's, the Tracking and Data Relay Satellite System (TDRSS) was added to the STDN. With this addition, the STDN provided the increased support required by user missions and allowed the closure of some STDN ground station sites. A key benefit of the STDN in the TDRSS era is that data flow between mission spacecraft and user ground station facilities is in real time.

The earth stations operating at eight locations around the world make up the Ground Spaceflight Tracking and Data Network (GSTDN). These earth stations track spacecraft during the launch and suborbital phases and usually in orbit. Three of the GSTDN ground stations located at Goldstone, CA, Madrid, Spain, and Canberra, Australia, provide primary support for high and synchronous orbit spacecraft and for the eccentric orbit spacecraft. A fourth GSTDN ground station at Fairbanks, AK, supports existing Earth orbiting spacecraft which are not compatible with TDRSS. Launch support facilities are located at Merritt Island, FL, with down-range facilities at Bermuda for east coast launches. The Vandenberg facility is operated by the USAF for west coast launches, while Wallops Island, VA, will continue to support a limited number of orbiting research satellites.

AN/SMQ-11 Weather Receiver Set

The AN/SMQ-11 weather receiver set receives weather information directly from the Defense Meteorological Satellite Program (DMSP) satellite, Television Infrared Observational Satellite (TIROS-N) polar-orbiting satellites, and Synchronous Meteorological Satellite - Geostationary Operational Environmental Satellite (SMS-GOES). The AN/SMQ-11 weather receiver set is a receive-only earth station, which will use frequencies in the bands 136-138 MHz (50K0V1D emission), 1690-1710 MHz (260KV1D emission), and 2200-2300 MHz (6M00G1D emission). The set will replace the currently deployed AN/SMQ-6 and AN/SMQ-10 receiver-recorder sets and will be located at 31 fixed shore sites worldwide, and on 44 ships at sea areas worldwide. The AN/SMQ-11 weather receiver set will provide real-time weather information to support ship movement decisions and operations.

Space Shuttle. Discussed previously in Section 5.

Space Station FREEDOM (SSF)

The SSF is a multi-purpose facility which will provide the U.S. with a permanent, manned orbital facility serving many functions including the following: a national laboratory in space for scientific research; a permanent observatory in space; a servicing facility for various free-flying spacecraft; a transportation node; an assembly facility; a manufacturing facility; and a staging base for space exploration. In addition to government use, the SSF will also be available for non-government and foreign use.

Launch and assembly of the various space station elements are scheduled for the mid 1990's and has a life expectancy of 20 years or more. The main platform, or core, will occupy a low-Earth orbit inclined 28.5°. The Polar Orbiting Platform, containing payloads such as remote sensors that do not require frequent servicing from the core, will occupy a sun-synchronous orbit inclined about 98°. Other elements include the free-flying spacecraft and various service and orbit transfer vehicles. Transportation to and from the Earth will be provided through the Space Shuttle. Telecommunications for the Space Station will be provided primarily by many existing NASA frequency resources including the TDRSS and its follow-on systems, the Tracking and Data Acquisition System (TDAS). The National Space Transportation System (Space Shuttle Orbiter, NSTS) will provide primary logistics support. The GPS is the most likely system to be used in conjunction with the SS traffic control function.

Strategic Defense Initiative (SDI) - Target Satellite System

The SDI is a major DOD program which will involve the extensive use of space systems. One component of the SDI, SDI Target Satellite System (SDI/TSS), is undergoing experimental testing. The purpose of the satellite experiment is to measure the temporal and spatial distribution of low-energy infrared, ultraviolet, and visible laser beams transmitted from designated ground sites and telemeter the measurement results to selected ground stations. At any one time this system will consist of four earth stations and up to two low-earth orbiting (463 km) satellites.

Laser experiments will be conducted from five possible sites: Maui, HI; China Lake, CA; White Sands, NM; Albuquerque, NM; and Westford, MA. Two telecommand/telemetry ground equipment packages will be transportable to allow them to be moved to various locations. Sites at Blossom Point, MD, and the Naval Research Laboratory (NRL) near Washington, D.C., will be used for house/station keeping and/or scheduling.

The systems uplink telecommand will operate on the frequency 142.650 MHz and the downlink telemetry operations will be conducted at 2286 MHz with a necessary bandwidth of 6.25 MHz. To date, no other SDI components have been presented to the IRAC Spectrum Planning Subcommittee.

Tracking and Data Relay Satellite System (TDRSS)

The TDRSS is a NASA program developed to reduce the cost and improve the efficiency of returning spacecraft gathered scientific data to Earth. In addition, real-time coverage of the low-orbit satellite can be provided on a more complete basis, as compared to the previous network of U.S. earth stations which can support a given space research mission for about 15 percent of the time due to visibility constraints. The TDRSS was principally designed to provide communication links between LEO spacecraft, including the Space Shuttle, and earth stations via geostationary satellites. It is an integral part of NASA's STDN and, when fully operational, will replace possibly six GSTDN from Hawaii to Africa.

The TDRSS at full operation, can track up to 26 satellites at a time, will ultimately consist of five geostationary Tracking and Data Relay Satellites (TDRS): four operational satellites located at 41°W, 62°W, 70°W, and 171°W and one in-orbit spare; and an earth station at White Sands, NM. The first satellite, TDRS-EAST or TDRS-1, was launched in April 1983 and positioned at 41° West Longitude. Unfortunately, a second satellite was lost with the Space Shuttle Challenger in January 1986. In 1988, a sophisticated TDRS (TDRS-3) was launched at 171° West Longitude to work in tandem with TDRS-1. The TDRS-3 allows mission control to stay in near-continuous contact with shuttle crews and low-orbit satellites.

Because of the importance in improving communications with future shuttle crews, NASA launched another satellite (TDRS-4) in March 1989. Described as the most complex non-military communications satellite, the TDRS-4 has dramatically improved communications with LEO spacecraft; in particular, the Space Shuttle. When TDRS-4 was deployed into orbit, NASA's TDRSS was completed and converted TDRS-1 into an in-orbit spare.

However, in early 1990, TDRS-1 was moved to 171° West to fulfill some of the functions of TDRS-3 which lost some K_u-band (13.775 and 15.0084 GHz) capabilities.[11] The TDRS-3 was shifted to 174° West Longitude, however, it still carries the bulk of the communications traffic in the satellite system's West position. Another satellite, TDRS-5, is scheduled for launch in May

[11] *Aviation Week and Space Technology*, McGraw-Hill publication, May 7, 1990.

1991 and will likely be placed in the West position to replace the weaker of the two existing satellites (i.e., TDRS-1 or TDRS-3).

Augmented TDRSS

The Augmented TDRSS will enhance the capacity of the TDRSS for contingencies with the increase in the number of satellites in the system and the addition of a second earth station. NASA, with the Augmented TDRSS, plans to place two additional TDRS satellites in geostationary orbit at 46° West and at 174° West, and establish an additional earth station at White Sands, NM.

Advanced TDRSS (ATDRSS)

The ATDRSS is being designed as a follow-on to the TDRSS and the Augmented TDRSS. The ATDRSS satellites will be phased in to replace satellites in the Augmented TDRSS network as they wear out or as the increased capacity is needed for mission support. Eventually, Advanced TDRSS satellites will replace all of the original TDRSS satellites. Initially, the ATDRSS will consist of three geostationary satellites to be launched beginning in 1997. In addition to the communication links available with TDRSS, certain ATDRSS plans call for space-to-space links in the 22.55-23.55 GHz, 25.25-27.5 GHz and 54.25-58.2 GHz ISS bands and feeder links in the 17.7-21.2 GHz and 27.5-31 GHz FSS bands. Portions of these bands are allocated for non-government or shared use, allowing ATDRSS to be used by commercial spacecraft.

SPACE RESEARCH SERVICE

P78-2 System - Discussed previously in Section 5.

P80-1 System - Discussed previously in Section 5.

P86-1/CRRES System - Discussed previously in Section 5.

International Ultraviolet Explorer (IUE)

The IUE was launched into an elliptical orbit in 1978 primarily to study celestial ultraviolet sources. The IUE is a cooperative effort by NASA, the United Kingdom, and the European Space Agency (ESA).

Dynamic Explorer A-B (DE-A, DE-B) System

The Dynamic Explorer (DE) mission involves two satellites placed into an elliptical orbit in December 1980. The purpose of the DE program is to study priority problems in space plasma physics. Each spacecraft will contain sensors and telemetering transmitters for relaying data to Earth for scientific study. The satellite network will consist of radio frequency links from the DE-A and DE-B spacecraft to currently existing STDN, and between the DE-B spacecraft and the TDRSS.

Another DE satellite, designated DE-1, was launched in August 1981 to investigate the Earth's electromagnetic field in an elliptical polar orbit.

Advanced Magnetospheric Particle Experiment/Charge Composition Explorer (AMPTE/CCE) System

Launched in August 1984, the AMPTE/CCE occupies a highly elliptical orbit. The satellite is used to conduct experiments to measure physical processes in the magnetosphere and ionosphere. The AMPTE/CCE program is an international cooperative effort consisting of three spacecraft. The CCE craft was launched by the U.S., while the other two were launched by the United Kingdom and the Republic of Germany.

The spacecraft, which transmits at 2271 MHz and receives at 2091.21 MHz, uses the STDN earth stations.

Earth Radiation Budget Satellite (ERBS)

The ERBS occupies a circular orbit inclined about 46°. Launched in October 1984, the ERBS is used to study processes related to the Earth's climate.

San Marco D/L System

The San Marco D/L satellite was launched in March 1988 on a Scout G-1 launch vehicle inclined at 2.9°. The system operates in conjunction with another satellite network, San Marco D/M, for the purpose of exploring the relationship between solar activity and meteorological phenomena. Together, they are also used to determine the solar influence on low-atmospheric phenomena through the thermosphere, and to measure the global ozone levels.

Cosmic Background Explorer (COBE) System

The COBE was scheduled for launch in May 1989 to explore and study diffuse radiation of cosmic origin between about 30 GHz and 300 THz. The transfer of data between COBE at sun-synchronous orbit (900 km) and TDRSS is conducted at 2287.5 MHz and 2106.4 MHz for COBE transmission and reception, respectively. A single earth station located at Wallops Island, VA, is used for data "dumps."

Hubble Space Telescope (HST) System

The HST will be the first complete observatory in space and will have an expected orbiting lifetime of 15 years. It is an unmanned astronomical observatory consisting of a Support System Module, an Optical Telescope assembly and a complement of scientific instruments. It will be used to probe the secrets of the universe and analyze light sources which cannot be detected by ground-based telescopes. It was launched by the Space Shuttle in April 1990 and required the complete shuttle payload bay service. The HST, although unmanned, can be serviced by astronauts during extra vehicular activity missions and can be returned to Earth for refurbishing. The HST will operate at a nominal altitude of 500 km with an angle of inclination of 28.5 degrees and a period of 95 minutes. The HST will receive command signals on 2106.4 MHz and will transmit housekeeping and some research telemetry on 2287.5 MHz and wideband data on 2255.5 MHz. All communications to and from the HST will be with the TDRSS.

Gamma Ray Observatory (GRO) Satellite System

The GRO satellite, scheduled for launch in January 1990, is a scientific observatory that is to be placed in a low Earth orbit to collect data for use in studying various sources of gamma rays. The satellite will operate in circular orbits with altitudes between 350 km and 450 km with an inclination angle of 28.5 degrees and an approximate period of 93 minutes. It will transmit on 2287.5 MHz and receive on 2106.4 MHz from the TDRSS.

Roentgen Satellite (ROSAT) System

A cooperative project with the Federal Republic of Germany, ROSAT will study individual x-ray sources and perform a general x-ray survey. ROSAT was scheduled for a February 1990 launch on a Delta II booster.

Ulysses

The primary objective of the Ulysses spacecraft is the study of various solar phenomena. Ulysses will also be used for study of interplanetary physics and the Jovian magnetosphere. Ulysses is scheduled for an October 1990 Space Shuttle launch.

Extreme Ultraviolet Explorer (EUVE)

The EUVE, to be launched in August 1991 by either the Space Shuttle or the Delta launch vehicle, will survey the entire celestial sphere in the extreme ultraviolet spectrum. The spacecraft, in near-circular orbit, will include four telescopes, operating only in the Earth's shadow.

X-Ray Timing Explorer (XTE)

The XTE spacecraft will study x-ray sources from a 500 km circular orbit inclined 28.5°. The XTE is scheduled for a November 1993 Space Shuttle launch.

International Solar Terrestrial Physics (ISTP) Program

A joint effort of NASA, ESA, and Japan's Institute of Space and Astronautical Science (ISAS), the ISTP program will consist of nine spacecraft studying the sun and the earth. ISTP missions are scheduled to begin in 1992.

Topography Experiment/Poseidon

The Ocean Topography Experiment (TOPEX)/Poseidon Project is a joint mission of NASA and the National Space Agency of France (CNES). The primary mission goal of this project is to support oceanographic research by precisely measuring the oceanic topography of the sea surface to further understanding of global ocean dynamics. NASA will provide the satellite and the TOPEX sensors (dual-frequency altimeter, microwave radiometer, laser retroreflector array, and GPS receiver). CNES will provide the Ariane launch and the POSEIDON sensors (solid-state altimeter and DORIS tracking system receiver). The TOPEX/POSEIDON spacecraft will be launched from the Centre Spatiales de Guiana in French Guiana on an Ariane 4 launch vehicle during December 1991. The proposed circular orbit will have an inclination angle of 63.13 degrees, a rotation period of 112.36 minutes and an altitude of 1333.8 km.

Tethered Satellite System (TSS)

The TSS is a joint undertaking between NASA and the Italian National Space Plan (PSN) of the National Research Council of Italy (CNR). The satellite is to be launched from and tethered to the shuttle. Initially, two missions for the TSS are planned. The first mission will deploy the satellite 20 km from the shuttle toward deep space on a conducting tether and study electrodynamics associated with the tether cutting the Earth's magnetic field. On the second mission the satellite will be deployed toward the Earth on a 100 km nonconducting tether to study the Earth's atmosphere. This second mission will require different equipment with different frequency requirements. The first flight is scheduled for January 1991, and the second within 18 months of the first.

The TSS will communicate with the shuttle presumably on the proposed frequencies at 2260 MHz (TSS transmit) and 2081.08332 MHz (TSS receive). NASA has stated that the frequencies will be noted for a period of five years. The nominal TSS mission duration is 36 hours which includes deployment, on-station and retrieval. The satellite will be deployed only once per shuttle flight.

Upper Atmospheric Research Satellite (UARS)

The UARS is a scientific satellite designed to perform extensive studies of the properties of the Earth's upper atmosphere between 20 km and 120 km. Experiments to be conducted include the better understanding of winds, atmospheric thermal balance, and the chemical processes inherent to the Earth's upper atmospheric region. The system consists of a UARS/TDRSS transponder and various UARS antennas.

The transponder will use the frequency 2287.5 MHz to transmit and the frequency 2106.4 MHz to receive. The UARS will use TDRSS to relay data to the Earth station located at White Sands Ground Terminal, NM. The cooperating relay satellites are the TDRS41W, TDRS62W, TDRS79W, and TDRS171W. The UARS may also transmit directly to the Earth stations located at Goldstone, CA; Canberra, Australia; and Madrid, Spain, for emergency backup only. The transponder has an emission designator of 5MG7D and peak envelope power of 0.7 dBW.

Chemical Release Module (CRM) Satellite System

The CRM is an unmanned satellite used to study the effects of solar wind on the Earth's magnetic field and on the Earth's atmospheric and ionospheric regions. The CRM was boosted into an elliptical orbit by the Space Shuttle. While in orbit, the CRM releases various chemicals for monitoring at selected altitudes and locations over the earth.

Command and control of the spacecraft on 2070 MHz and satellite housekeeping telemetry on 2248 MHz is provided by the TDRSS. An emergency backup to the TDRSS is affected with the GSTDN ground stations.

The CRM was launched in 1984 and planned to operate through 1991.

Astronomical (ASTRO) - Shuttle Pallet Satellite (SPAS)

ASTRO-SPAS is a program managed by the Federal Ministry for Research and Technology, Germany. It will be launched on the National Space Transportation System (NSTS), deployed, and then retrieved on the same mission. ASTRO-SPAS is a telescopic payload which will make scientific measurements by scanning the Earth's horizon and atmosphere on one mission and scanning deep space on a subsequent mission using a passive sensor to scan. The satellite communications links will be through the NSTS Orbiter via the Payload Interrogator (PI). The ASTRO-SPAS transmits data at 2225 MHz to the PI and receives data from the PI on 2048.85 MHz. Approximately 30 minutes of support every eight hours is anticipated for normal operations. The total length of one ASTRO-SPAS mission is limited by the duration of the NSTS orbiter mission, nominally four to five days.

Two missions are planned. An initial launch is scheduled for September 1992 and a second launch is scheduled for May 1993.

ITV, SGLS. Discussed previously in Section 5.

EARTH EXPLORATION SERVICE (EES)

LANDSAT Satellite System

The LANDSAT system consists of two polar-orbiting satellites used for detection of visible and near infrared radiation reflected by the Earth and for mapping. LANDSAT 4, launched in July 1982, developed technical problems that made the launch of an additional satellite necessary. LANDSAT 5 was launched in March 1984. Although initially operated by NASA, responsibility for the LANDSATS was transferred to the National Oceanographic and Atmospheric Administration (NOAA) beginning in January 1983. In 1985, the Earth Observation Satellite Company (EOSAT) was formed to take over operation of the LANDSAT program under the Land Remote-Sensing Commercialization Act of 1984. In 1989, LANDSAT 6 was under system review for operational status. By agreement between NTIA and NESDIS, NOAA is to be licensee for LANDSAT 6.* LANDSAT satellites employ both TDRSS data links and direct links to earth stations.

NIMBUS-7 Satellite System

Launched in October 1978, NIMBUS-7 occupies a polar sun-synchronous orbit. The satellite is used for atmospheric surveillance and mapping.

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* National Environmental Satellite, Data, and Information Service.

Geosynchronous Operational Environmental Satellite (GOES) System

GOES is part of the International Geostationary Meteorological Satellite Data Collection System (IGMSDCS) which also includes several satellites of other nations. The latest launched GOES satellites are the GOES 6, launched in April 1983, and GOES 7, launched in February 1987.[a] These satellites are located at 135.1° West and 74.9° West, respectively. The latter satellite includes a satellite EPIRB experiment.[b] In addition to MetSS frequencies, GOES satellites also operate in the 2025-2110 MHz and 2200-2290 MHz EES bands.

The current GOES system, consisting of seven satellites, is being replaced in order to provide more timely and higher resolution weather forecasts over the Continental U.S., and to provide an improved system for the collection and dissemination of meteorological data. The next generation of NOAA's GOES weather satellites include GOES-I through GOES-M with scheduled launch dates between March 1990 and March 1997. They will eventually replace the current GOES satellites at longitudes of 75 and 135 degrees west.

NOAA Television Infrared Observational Satellite (TIROS) System)

Current TIROS series satellites include NOAA 9, launched in December 1984, and NOAA 10, launched in September 1986. These satellites measure atmospheric temperature and humidity, surface temperature, cloud cover, water-ice boundaries, and proton and electron flux near the Earth. The TIROS satellites also carry EPIRB system transponders.

SPACE OPERATION SERVICE

Array of Low Energy X-rays Imaging Sensors (ALEXIS). Discussed previously in Section 5.

Defense Satellite Communications Systems (DSCS). Discussed previously in Section 5.

Fleet Satellite Communication-C (FLTSATCOM-C). Discussed previously in Section 5.

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[a] These Systems are operated by the U. S. Department of Commerce.

[b] Emergency Position-Indicating Radiobeacon.

Inertial Upper Stage (IUS). Discussed previously in Section 5.

Orbiting Maneuvering Vehicle (OMV)

The OMV is a multi-purpose vehicle that will be launched and returned to Earth by the shuttle. The vehicle will deliver, retrieve, reboost and deboost payloads and provide viewing for teleoperations. It will operate out of the Shuttle and Space Station (SS). The operational altitude of the OMV will range from 185 km to approximately 2800 km. The OMV missions are to be about 20-30 hours in length. The OMV is capable of supporting missions of up to seven days. Additionally, the OMV can survive in orbit for nine months in a contingency mode, during which time on board transmitters will be powered down. The OMV will be controlled from the ground through TDRSS, except when it is within the SS control zone (approximately 32 km) when it will be under control of the SS. The OMV also plans to use the GPS Network during its mission. Also, the vehicle will include a rendezvous radar. This low-powered radar (1 to 4 W peak power) will be used in all rendezvous operations with payloads, orbiter and SS.

The OMV is scheduled for operation (first flight) in summer 1991.

POLAR Plasma Laboratory and WIND Spacecraft*

The POLAR and WIND spacecraft are parts of the Global Geospace Science (GGS) support program of the International Solar Terrestrial Program (ISTP). The objective of the GGS initiative is to measure, model, and quantitatively assess the processes in the Sun-Earth interaction chain by the use of GGS spacecraft WIND and POLAR. Specific GGS objectives include studying the solar wind-magnetosphere energy coupling and the global-magnetosphere transport. The major objective of the ISTP GGS program is to make measurements from these two spacecraft simultaneously with measurements from the Institute of Space and Astronautical Science (ISAS) Geomagnetic Tail Laboratory (GEOTAIL) spacecraft and the Air Force CRRES. GEOTAIL is part of the ISTP Collaborative Solar Terrestrial initiative and makes measurements in the geomagnetic tail. The CRRES spacecraft will make complementary magnetospheric measurements in the equatorial region.

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* The POLAR and WIND Spacecraft have dual service (Earth Exploration and Space Operation Services).

The WIND and POLAR spacecraft will be placed in complementary orbits of each other. However, the WIND is scheduled to be launched six months (December 1992) ahead of the POLAR (June 1993) and are expected to have a lifetime of 24 and 18 months, respectively. The tracking, telemetry and command frequency requirements pertinent to the 2 GHz operations are for the frequencies 2094.9 MHz (uplink) and 2275 MHz (downlink) for WIND and 2085.69 MHz (uplink) and 2263 MHz (downlink) for POLAR.

FIXED SERVICE

Point-to-Point (LOS)

As is the case in the 1710-1850 MHz band, the 2200-2290 MHz band also supports medium capacity fixed microwave links. In this band, the point-to-point (LOS) class of system is basically similar in function to the LOS system described earlier, except for the use of trunking where it is common in the 1710-1850 MHz band, but slightly different in technical characteristics. A total of 266 assignments are currently registered in the GMF having the station class specified above. The Army, with 110 assignments, is the predominant user of this type of fixed system in support of its backbone, radio relay, testing microwave systems, hydrological and construction operations. The Coast Guard (CG) comes next with 29 assignments. Figure 5-7 (Vessel Traffic System) is a representative of a typical CG network.

Telecommand and Telemetering Fixed System

There are only two assignments in the GMF for this station class (FXD, FXDR). One at 2206.5 MHz for digital command from a U.S. Navy shore station in North Carolina to a platform off shore for the platform to release stored data. The system transmits data on the hour for a period of less than 60 seconds for each transmission which occurs three times during a 24 hour period. The other assignment is for NASA at 2215.5 MHz in support of the Goddard Space Flight Center's Solar Pointing AEROBEE Rocket Control System (SPARCS) Program). The assignment is solely for ground testing conducted inside a metal building of equipment for use in the SPARCS program. The system uses an emission type of 6M00G9D, 8 watts of power and a dipole antenna (0 dBi gain).

The telemetering fixed (FXE or FXER) systems are basically used for transmission from devices or equipment to a central controller. There are 40 current assignments in the GMF bearing the FXE (NO FXER) station class designator. The majority of these assignments, approximately 29 assignments, belong to DOE. Out of these 29 assignments, 12 are used for the Nevada Automated Diagnostic System (NADS) timing and control data at the Nevada Test Site (NTS). These assignments are characterized by the relatively low power level of 4 watts, an emission designator of 2M00F9D, and an antenna gain of 30 dBi (transmit/receive). The telemetering systems used at NTS include the Farinon Electric (FEC) LR2-2000, FEC FM-2000 and TERRA COM (TCM) - 601 systems. The rest of DOE's assignments are mostly in support of test programs such as: weapons testing, environmental testing for setting new telemetry equipment over a distance of three-quarters of a mile, etc.

NASA has six assignments for the purpose of telemetering stress, vibration and shock data during high-G drop tests of booster system components at Huntsville, AL. The assigned frequencies range from 2247.5 MHz to 2277.5 MHz. The assignments are characterized by a power level of 10 watts and an emission designator of 500K00F9D.

The Army has four assignments in the following discrete frequencies: 2201.5 MHz, 2223.5 MHz, 2225.5 MHz and 2261.5 MHz. The assignments are characterized by the following parameters: 5 watts of power, 0-29 dBi antenna gain and bandwidths of either 500 kHz, 600 kHz or 2.2 MHz. These assignments support the Army's research, development, testing and evaluation program and telemetry operations at proving grounds in UT and AZ.

The Air Force has an assignment at 2225.5 MHz for boresight calibration of test site instrumentation. The assignment has a very narrow bandwidth of 100 Hz and low power of 0.1 watts.

TACTS/ACMI. Discussed previously in Section 5.

MOBILE SERVICE

Air/Grd, Air/Air, and Grd/Grd Video and Data Links

This functional class of systems represents the largest group of assignments, approximately 1322, in this band. This band has become one of the principal bands supporting telemetering for military operations since the closing of the 225-400 MHz band for this function. These systems primarily provide real-time data from remotely piloted vehicles, drones, and missiles. Locations of these systems are somewhat diverse but the majority are on military test ranges in the Southwest U.S. and on the East Coast. The majority use low gain or omnidirectional antennas and power levels of less than 20 watts. The U.S. Army and Air Force, however, operate systems with power levels of 50 watts to 100 watts at their test ranges in the midwest, southwest, and southeast U.S.

The Army, for example, has eight assignments to support range telemetry at Redstone Arsenal, AL. The operating frequency range of the system starts at 2205.5 MHz with a 10 MHz increment up to 2265.5 MHz and including the frequency 2279.5 MHz. The system operates at a power level of 100 watts with a 1M00P7D emission designator and uses a whip (transmitter; 2 dBi gain) and parabolic (receiver; 18 dBi gain) antennas. In addition, the Army operates systems that are band-tuned in the 2200-2290 MHz band. These systems use high gain (29-38 dBi) antennas and are authorized anywhere in the U.S.; particularly, in Army bases in the following states: NM, UT, CO and TX. The Air Force also operates a band-tuned system (2200-2300 MHz band) at Eglin Air Force Base, FL. The system employs either a 1M00G7W (100 watts) or 3M00G7W (50 watts) emission designator. The Air Force has two other assignments at 2215.5 MHz and 2257.5 MHz outside the CONUS (Marshall Island). Both assignments are for flight telemetering mobile systems with 80 watts of power, 500K00F9D emission designator, and 45 dBi antenna gain.

The systems or equipments discussed below are typical examples of the low-power telemetering mobile systems pertinent to the band. These systems are either operational or still at their experimental stages. The ER-2 High Altitude Aircraft Telemetry System is an example of the medium-to-high-power system.

<u>Charged Coupled Device (CCD) Seeker</u>

The CCD Seeker System is designed to provide data and video information for monitoring the flight testing of missiles. The system consists of two on-board transmitters operating in the 1710-1850 MHz (video) and 2200-2290 MHz (data) bands. Both transmitters operate at 3 watts and utilize omnidirectional antennas.

<u>AN/DKT-71</u>

The AN/DKT-71 telemetry transmitter sends information from the Standard Missile 2 to ground station telemetry receivers (Microdyne MR1200 receivers) during test flights and bench evaluation of the missile. The AN/DK-71 telemetry transmitter will operate in the 2209.9-2279.1 MHz frequency range with a mean output power of 5 watts into a conformal array antenna with up to 5 dBi gain. Each missile will be able to use one of seven discrete frequencies (2212.5, 2224.5, 2232.5, 2252.5, 2262.5, 2272.5 and 2276.5 MHz) in this frequency range. The transmitter uses a PCM Frequency Modulation scheme and has an emission designator of 5M04F7D.

Stage 3 operation will be at PMTC, China Lake and White Sands Missile Range. Stage 4 operation will be at National service and test ranges in the US&P. The system will replace the AN/DKT-53 and AN/DKT-53A for several applications.

Titan III and IV

The AF Titan telemetry system will transmit telemetry data to ground stations and will be operational from launch to stage 2/3 separation. While the Titan III's are usually launched at Cape Canaveral, FL, the Titan IV's will be used at Cape Canaveral AFS, FL, and Vandenberg AFB, CA. The system will operate in the 2200-2300 MHz frequency band with an average output power of 14 W and a mainbeam antenna gain of 7.5 dBi.

Vector T-100 S/L Series

The Vector T-100 S/L Series telemetry transmitters actually consist of a series of equipments, all with similar operating characteristics. Specifically identified are the Vector T-102S/L, T-102SE/LE, T-105S/L, T-105SE/LE, T-108S/L, and T-110LE Transmitters. The system is used to provide real time, highly reliable FM/FM and PCM/FM telemetry links from airborne vehicles, including missiles, to and from other airborne or ground facilities. The system operates at a power level range of between 2 watts and 10 watts. The area of operation is the US&P.

Omnitek TX501

The Navy's Omnitek TX501 telemetry system will be used to collect and transmit telemetric information from the Advanced Medium Range Air to Air Missile (AMRAAM) during warhead launch tests. The system will be used to evaluate missile performance during warhead launch tests. The system will operate in the 2200-2290 MHz band with a 3M78F1D emission at a mean power of 2 watts. The Stage 3 areas of operation include military test ranges at Eglin Air Force Base, FL; Naval Weapons Center, CA; Pacific Missile Test Center, CA; and White Sands Missile Range, NM.

Microcom T902

The Navy's Microcom T902 transmitter is part of the telemetry transmission system for the sidewinder missile recovery package. The intended operating data rate of PCM/FM telemetry downlink from Microcom T902 transmitter to ground receiver is 500 kbps. The transmitter will operate in the 2200-2290 MHz band with a 1M35F2D emission at a mean power of 2 watts. The intended operating frequencies are specified at 2202.5, 2209.5, 2211.5, 2213.5, 2214.5, 2217.5, 2218.5, 2220.5, 2222.5, and 2225.5 MHz.

The Microcom T902 transmitter, which is a commercially available, off-the-shelf equipment, will replace some applications of the AYDIN Vector T-202S transmitters. The Stage 4 areas of operation include military test ranges in the US&P at the Naval Weapons Center, CA; Pacific Missile Test Center, CA; Eglin Air Force Base, FL; and Tyndall Air Force Base, FL. The international area of operation includes Clark Air Force Base, Republic of the Philippines.

Earth Resources (ER-2) High Altitude Aircraft

The purpose of the system is to provide for the transmission of scientific data from the instruments on board an ER-2 aircraft to a ground station. The telemetry data link will provide "quick look" capability of the data on the ground in real time, allowing experimenters to advise the pilot to seek a better field of view, to permit remotely located scientists to examine data, and to monitor the experimental instruments on board the aircraft.

The ER-2 consists of an airborne transmitter and ground receiver. Operations will mainly be confined to within 185 km of Cape Kennedy Space Center and 560 km of the NASA/Ames Research Center at Moffett Field, California. The ER-2 will fly at altitudes of 13 km to 18 km. The ER-2 will also be used in support of state and Federal fire control efforts in the western part of the U.S. A NASA transportable ground station will support flights beyond 300 NM of Moffett Field. The transmitter has a power of 40 watts, an omni antenna (1 dBi), and a bandwidth of approximately 3.5 MHz but not to exceed 8 MHz. The receiver has an antenna gain of 16 dBi. NASA has proposed four possible frequency bands for ER-2 operations. They are 902-928 MHz, 1435-1530 MHz, 2200-2290 MHz, and 1626.5-1645.5 MHz in order of preference.

M/A COM Model MA-2.5MX and Model Super 2MR

An example of this system is the Army's M/A COM Model MA-2.5MX Transmitter and Model Super 2MR Receiver. The MA-2.5MX Transmitter will transmit video test data and audio signals from mobile vehicles to a central base station over a distance of 100 meters to 8 kilometers during field test operations. The system has the capability to operate in the 2200-2450 MHz band. The proposed system will replace three AACM Model AT-3610S-V systems and one AT-1410S-V system whose operations on 2205.5, 2225.5, 2245.5 and 2265.5 MHz will eventually be phased out. The system is planned for use at Ft. Bliss, Texas, and Ft. Knox, Kentucky.

Tethered Radar Balloons/SEEK SKYHOOK. Discussed previously in Section 5.

Scoring Systems (Telemetry Link)

BHI. Discussed previously in Section 5.

FAST. Discussed previously in Section 5.

AN/USQ-X

The AN/USQ-X Scoring System is an RF miss-distance indicating system consisting of an MDI on an aerial target, a telemetry downlink, and a receiving ground station. The MDI will gather miss-distance and closing velocity data on high- and low-altitude intercepts between aerial targets and incoming projectiles. The projectiles' velocities, miss-distances, and other intercept statistics will then be sent via the telemetry downlink to the ground receiving station for real-time processing and display. The scoring system will be compatible with many types of targets that vary in speed and altitude. The types of projectiles that can be fired at these targets range from 3-inch-diameter gunnery rounds, to high-performance missiles. Simultaneous operation of up to six systems is possible during multiple target presentations, with each system using independent telemetry downlinks. Figure 6-1 shows the AN/USQ-X scoring system configuration. The figure is also a representative of a typical configuration of an airborne scoring system.

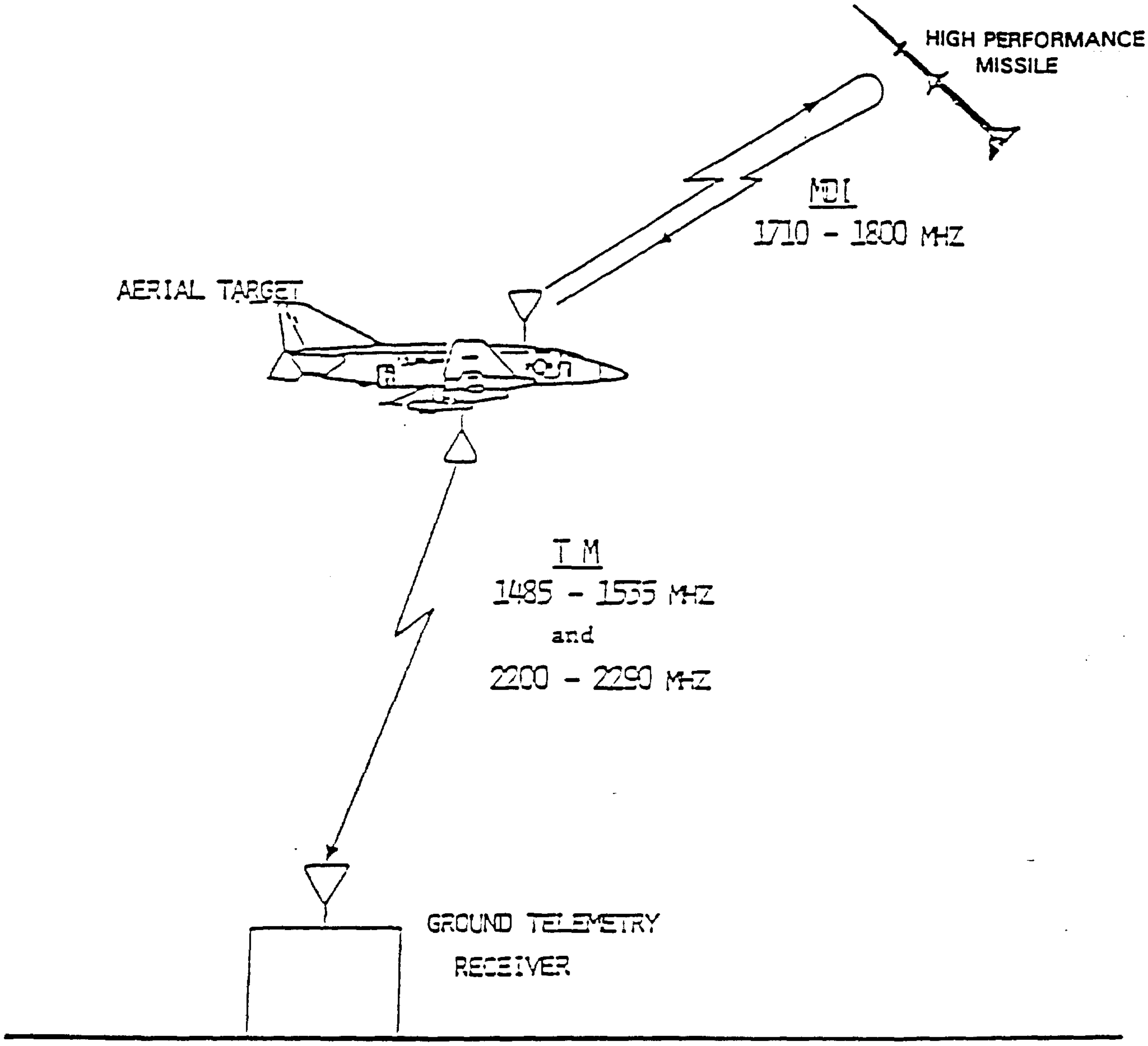

Figure 6-1. Typical AN/USQ-X Scoring System Configuration.

AN/DSQ-50

The system is used in scoring applications for missile and projectiles 76 mm and larger. The miss distance radar is a pulsed doppler radar which detects these objects within a range of 75 feet from the target antenna. The telemetry transmitter is used to telemeter the information to a ground receiver. The pulse coded modulation telemetry is proposed to operate in the 22000-2290 MHz band using the 1M00F1D emission designator. The system will replace the AN/DSQ-37.

EXPERIMENTAL SERVICE

There are approximately 538 assignments listed in the GMF for equipment operating in the band and in the Experimental Service. Of these assignments, the majority belongs to the Experimental Testing station class (XT) with approximately 446 assignments. This type of station class has been described previously. The rest of the assignments are distributed among the other types of station classes in the Experimental Service. The Experimental Research (XR) with 24 assignments has also been previously discussed. The Experimental Contract Developmental (XC) (49 assignments) and Experimental Developmental (XD) (18 assignments) station classes are for stations used in the evaluation or testing of electronic equipment of systems in a design or developmental stage. The best used station class, the Experimental Composite (XU) with one assignment, represents a composite of two or more experimental categories and is used for experiments in radar cross section and transmission of video data. These assignments have a specified expiration date.

APPENDIX A

ESTIMATED FEDERAL GOVERNMENT'S INVESTMENT FOR FIXED SYSTEMS IN THE 1710-1850 MHz AND 2200-2290 MHz BANDS

The approach used to estimate the total Federal Government's investment for fixed, line-of- sight, point-to-point systems in the 1710-1850 MHz and 2200-2290 MHz bands is based on the following:

a) The specified cost provided by an agency is used whenever available.

b) If a cost is not specified, a reasonable cost is derived based on information provided by an agency (e.g., a certain percentage of the total investment is allotted to a specific band).

c) If the information provided is insufficient to determine an initial cost and an agency's cost per link for a specific band is known, this value is multiplied by the known number of fixed links in the band.

d) If the cost per link is not known and there is no other available information with regards to an agency's cost investment in a band, a value of $50,000 per link is multiplied to the agency's total fixed assignments (i.e., FX, FXR, FXE, FXD) in the band to derive an initial cost investment.

e) When specific cost estimate is not available, the replacement cost is calculated by multiplying the number of new stations by $250,000/station and adding the product to the initial cost.

Extracts from some of the Federal Agencies' input response to the NTIA memo, dated December 13, 1989, with regards to the Emerging Telecommunications Technology Act are presented below. These documentations, together with some other sources (e.g., SRV/GMF) were used to derive the total estimated initial and replacement costs of the fixed systems for each agency.